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Empowering Rural Communities through University-Community Engagement: Advancing Sustainable Rural Development through School-Based Initiatives

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Abstract

University-community engagement plays an important role in addressing educational and developmental challenges in rural communities. This study examines how university-supported school-based initiatives contribute to knowledge transfer, practical skills development, institutional capacity building, and sustainable rural development. Adopting a qualitative descriptive multiple-case study approach, the study compares two aquaculture initiatives implemented at High School Pulau Nyior and Sungai Taka Elementary School in Malaysia. The analysis draws on existing project documentation and reported implementation outcomes to explore university-school collaboration, experiential learning, student participation, and institutional development. The findings indicate that both initiatives created opportunities for practical learning and strengthened school-level educational resources. At High School Pulau Nyior, technology-assisted aquaculture activities introduced students to digital applications, production processes, and entrepreneurial awareness, while fish sales generated revenue to support educational needs. At Sungai Taka Elementary School, supervised aquaculture activities encouraged student participation, responsibility, and early exposure to practical skills. The subsequent introduction of hydroponic activities also reflected opportunities for expanding school-based learning initiatives. Drawing on these findings, the study proposes a University-Community Engagement Framework for Sustainable Rural Development, integrating institutional collaboration, knowledge transfer, experiential learning, and project continuity. The study highlights the potential of university-community partnerships to strengthen rural educational capacities while emphasizing the importance of stakeholder participation, local ownership, and sustained institutional support.

Keywords

University-Community Engagement, Rural Development, School-Level Capacity Building, Experiential Learning, Knowledge Transfer, School-Based Initiatives, Sustainability

1. Introduction

Universities are increasingly recognized as important contributors to sustainable development through their roles in education, research, knowledge transfer, and community engagement. Beyond their traditional academic responsibilities, higher education institutions are expected to address societal challenges by establishing collaborative relationships with local communities and facilitating initiatives that promote social inclusion, capacity building, and economic opportunities. University-community engagement has consequently emerged as an important mechanism for connecting academic expertise with community needs and supporting locally responsive development. Diong et al. (2025) examined the contribution of service-learning to university engagement in Malaysia. Similarly, Lang et al. (2024) emphasized the importance of knowledge co-production and collaborative partnerships in supporting rural revitalization, demonstrating how universities can contribute to development processes through meaningful interactions with local stakeholders.

Rural communities frequently encounter challenges associated with limited access to educational resources, technological infrastructure, specialized training, and opportunities for practical skills development. Addressing these challenges requires approaches that integrate education, community participation, institutional collaboration, and locally appropriate development strategies. Universities can contribute to these efforts by mobilizing academic knowledge, technical expertise, and external partnerships to strengthen community capabilities. Lammert et al. (2025) examined a needs assessment supporting a rural K-12 school-university partnership, underscoring the relevance of local priorities in the design of engagement initiatives.

University-community engagement is particularly relevant when educational institutions collaborate with schools to introduce practical learning opportunities and strengthen local educational capacities. School-based initiatives provide structured environments through which students can acquire knowledge, develop practical skills, and participate in activities connected with their surrounding communities. Ferrell and Tharpe (2024) demonstrated how university-school partnerships can strengthen rural science education through professional development, place-based learning, and continued institutional support. Similarly, Kizys et al. (2025) examined the integration of community assets, place-based education, and career development in rural schools, highlighting the potential of project-based learning to connect educational experiences with locally relevant resources and

future opportunities.

The educational value of university-supported community initiatives can also be understood through experiential learning, which emphasizes knowledge development through practical participation and reflection. Community-based learning provides opportunities for students to connect theoretical concepts with real-world situations while developing awareness of social responsibilities and practical challenges. Frimpong et al. (2024) highlighted the role of experiential learning in strengthening connections between university education and community engagement. Furthermore, Diong et al. (2025) demonstrated that service-learning within Malaysian higher education can integrate academic learning with community participation, providing students with opportunities to apply knowledge while responding to community needs. These studies suggest that educational engagement initiatives can create opportunities for reciprocal learning when academic institutions and community stakeholders participate meaningfully in implementation.

Within Malaysia, university-community engagement has gained increasing attention as an approach to connecting higher education institutions with local development priorities. The Service-Learning Malaysia-University for Society initiative, commonly known as SULAM, represents one example of efforts to integrate academic learning with community-based activities. Hanafiah (2024) examined service-learning initiatives in Kedah and demonstrated how university-supported environmental activities could connect academic knowledge with community participation. Misiran et al. (2025) described a technology-assisted Malaysian community STEM engagement program. Related university-school partnership studies have also examined collaborative knowledge production (Guo & Lin, 2025) and teacher development (Hadar & Baharav, 2025).

The growing emphasis on community engagement also reflects recognition that sustainable development requires more than short-term interventions or the provision of physical resources. Meaningful development depends on the ability of participating institutions and communities to acquire knowledge, develop practical capabilities, and maintain activities beyond initial external support. Lang et al. (2024) emphasized that collaborative knowledge production can strengthen locally responsive rural development strategies. Similarly, Diong et al. (2025) examined how service-learning connects university education with community participation. These perspectives suggest that university-supported initiatives should be evaluated not only according to immediate project outputs but also in relation to institutional capacity building, stakeholder participation, and opportunities for continued implementation.

School-based initiatives provide a particularly relevant context for examining these relationships because schools can function as platforms for practical education, knowledge transfer, and community participation. Activities involving agriculture, environmental management, digital technologies, and small-scale entrepreneurship can introduce students to locally relevant skills while strengthening

educational resources. However, the design and implementation of such initiatives may differ according to students' educational levels, institutional capabilities, technological resources, and community characteristics. At the elementary school level, practical learning may emphasize foundational responsibilities, cooperation, and early exposure to livelihood-related activities. At the high school level, students may participate in more complex activities involving technological applications, production management, and entrepreneurial awareness. These distinctions suggest that school-based university engagement initiatives should be adapted to the educational and developmental characteristics of participating students.

Despite increasing scholarly attention to university-community engagement, service-learning, and rural educational partnerships, further research is needed to understand how university-supported initiatives contribute to institutional capacity development across different school settings. Existing studies have examined rural university partnerships (Lammert et al., 2025; Ferrell & Tharpe, 2024), knowledge co-production in rural development (Lang et al., 2024), and experiential learning through community engagement (Diong et al., 2025; Frimpong et al., 2024). However, these studies address different institutional contexts and developmental objectives. Further comparative examination may therefore provide insights into how university-led school initiatives combine knowledge transfer, practical learning, stakeholder collaboration, and institutional continuity across elementary and high school environments.

Against this background, the present study examines two university-supported school-based aquaculture initiatives implemented in rural Malaysia: High School Pulau Nyior in Kedah and Sungai Taka Elementary School. Both initiatives were designed to introduce practical aquaculture activities while encouraging student participation and school-level capacity development. However, their implementation approaches differed according to educational context and available resources. The high school initiative incorporated digital monitoring technology into aquaculture activities and introduced students to production-related processes and basic entrepreneurial experiences. In contrast, the elementary school initiative emphasized supervised practical learning, responsibility, cooperation, and early exposure to livelihood-related skills.

The purpose of this study is to examine the role of university-community engagement in advancing sustainable rural development through school-based initiatives. Specifically, the study seeks to: 1) examine how university-community partnerships facilitate knowledge transfer and practical skills development; 2) explore the contributions of school-based initiatives to student participation, practical learning opportunities, and school-level capacity building; 3) compare the implementation processes and documented outcomes of initiatives conducted at elementary and high school levels; and 4) propose a conceptual framework illustrating how university-community engagement may support sustainable rural development.

This study contributes to the literature by integrating university-community collaboration, knowledge transfer, experiential learning, and institutional sustainability within a comparative framework involving two educational settings. Rather than focusing exclusively on aquaculture production or individual learning outcomes, the study examines how collaborative relationships and school-based practical activities may strengthen institutional capacities and create opportunities for longer-term rural development. The findings are expected to provide context-specific insights for universities, schools, policymakers, and community organizations seeking to design educational engagement initiatives that are locally relevant, participatory, and potentially sustainable.

2. Literature Review

2.1. University-Community Engagement and Rural Development

University-community engagement has become an increasingly important dimension of higher education institutions' contributions to sustainable development. Beyond their traditional responsibilities for teaching and research, universities are expected to mobilize academic knowledge, technical expertise, and institutional resources to address societal challenges. This expanded responsibility recognizes that universities can contribute to community development by establishing collaborative partnerships, facilitating knowledge exchange, and supporting locally relevant initiatives. Recent discussions of rural anchor institutions and university engagement highlight the importance of institutional relationships and community perspectives (Harvey et al., 2024; Jenks et al., 2025; Nemadodzi & Nevhudoli, 2025; Paulson & Davis, 2024).

University-community engagement is generally characterized by relationships that connect academic institutions with external stakeholders through shared activities and mutual learning. However, the developmental value of such engagement depends on the extent to which community members participate in identifying priorities, implementing activities, and maintaining outcomes. Lang et al. (2024) examined university engagement in rural revitalization in China and demonstrated the importance of knowledge co-production among universities and local stakeholders. Their research emphasized that rural development benefits from collaborative arrangements that integrate academic expertise with local knowledge rather than relying exclusively on externally developed interventions.

The importance of university engagement is particularly evident in rural communities, where educational institutions may encounter limitations in access to specialized training, technological resources, and opportunities for practical skills development. University-supported initiatives can help address these constraints by introducing technical knowledge, strengthening institutional relationships, and providing opportunities for applied learning. Nevertheless, the effectiveness of these initiatives depends on their responsiveness to local needs and the capacity of participating institutions to sustain activities.

University-school partnerships represent one approach through which aca-

demic institutions can contribute to rural educational development. Ferrell and Tharpe (2024) examined a partnership designed to strengthen rural science education and highlighted the importance of collaboration between universities and school districts. Their study illustrates how higher education institutions can contribute to educational development through specialized expertise and institutional support.

Similarly, Kizys et al. (2025) investigated place-based education and project-based learning in rural middle schools. Their findings demonstrated the potential of partnerships involving educators and community stakeholders to connect academic learning with local resources and career-related experiences. However, the study also identified challenges associated with implementing project-based learning practices, particularly in relation to instructional design and assessment.

Within Malaysia, Diong et al. (2025) examined service-learning at a university and found that students associated the approach with experiential learning, academic activities, and community service. Their findings highlight the potential of community engagement to connect university education with societal needs, while also indicating that institutional implementation may remain uneven.

Collectively, these studies suggest that university-community engagement can contribute to rural development when partnerships extend beyond short-term assistance and create opportunities for reciprocal learning and institutional capacity development. However, the outcomes of engagement initiatives may vary according to community characteristics, stakeholder participation, resource availability, and institutional arrangements.

2.2. Knowledge Transfer and Community Capacity Building

Knowledge transfer is a central mechanism through which university-community engagement may contribute to educational and community development. It involves the sharing, adaptation, and application of knowledge, technical expertise, and practical skills among academic institutions and community stakeholders. In rural settings, knowledge transfer is particularly relevant when universities introduce resources or capabilities that participating institutions may not otherwise possess.

Traditional approaches to knowledge transfer often emphasize the movement of expertise from universities to external beneficiaries. However, this perspective may overlook the importance of local knowledge and community participation. Lang et al. (2024) demonstrated that university-supported rural revitalization can involve knowledge co-production, whereby academic institutions and community stakeholders contribute different forms of knowledge to development processes. This perspective suggests that effective engagement requires reciprocal interaction rather than one-directional dissemination.

Community capacity building extends beyond the acquisition of technical knowledge. It also involves strengthening organizational capabilities, developing confidence in undertaking responsibilities, and improving the ability of local in-

stitutions to manage activities. For school-based initiatives, capacity building may occur through teacher training, student participation, practical demonstrations, and the establishment of facilities that support continued learning. Work on community engagement in agricultural universities also identifies institutional challenges in sustaining engaged scholarship (Hjortsø et al., 2026).

The relationship between knowledge transfer and experiential learning is particularly important in educational partnerships. Frimpong et al. (2024) explored community-based experiential learning among undergraduate students and highlighted how engagement activities connected academic learning with practical community experiences. Their study demonstrates the educational potential of learning environments in which participants encounter real-world situations and apply knowledge beyond conventional classroom settings.

In Malaysia, Diong et al. (2025) similarly identified experiential learning as an important dimension of university service-learning. Their findings indicate that community engagement can provide opportunities for students to connect academic knowledge with practical activities. Nevertheless, the experiences of university students should not be assumed to be identical to those of elementary or high school students, whose learning needs and responsibilities differ.

Knowledge transfer within school-based initiatives therefore requires attention to the characteristics of participating students and the capabilities of teachers and school administrators. At the elementary school level, practical activities may emphasize basic knowledge, observation, and supervised responsibilities. At the high school level, activities may incorporate more complex technological applications, operational decisions, and production-related experiences.

Importantly, the provision of technical equipment does not necessarily demonstrate successful knowledge transfer. The developmental value of such resources depends on whether participating institutions acquire the knowledge and capabilities necessary to use and maintain them.

Accordingly, knowledge transfer and capacity building should be examined as interconnected processes involving access to expertise, opportunities for practical application, institutional learning, and the development of local capabilities.

2.3. School-Based Initiatives and Experiential Learning

Experiential learning provides an important educational foundation for understanding how school-based community initiatives may contribute to students' development. Unlike approaches that emphasize knowledge acquisition primarily through classroom instruction, experiential learning connects educational activities with practical participation, application, and reflection.

School-based initiatives involving agriculture, environmental management, technological applications, and community projects can create opportunities for students to apply knowledge in meaningful contexts. These activities may expose students to practical responsibilities, collaborative tasks, and locally relevant challenges. Research on aquaponics implementation in schools illustrates the practical

constraints of introducing integrated aquatic and plant-growing systems, although aquaponics is distinct from the aquaculture activities examined here (Oliveira et al., 2025).

Frimpong et al. (2024) demonstrated that community-based experiential learning can enrich students' educational experiences by connecting academic knowledge with practical engagement. Their findings support the broader educational value of integrating learning activities with real-world situations. However, the transferability of these findings to younger students requires consideration of differences in developmental stages and educational contexts.

Place-based education provides a complementary perspective by emphasizing the integration of local environments, community resources, and practical experiences into educational activities. Kizys et al. (2025) examined the implementation of place-based and project-based learning in rural educational settings and highlighted the potential of community connections to support career awareness and locally relevant learning.

Their findings are particularly relevant to school-based aquaculture initiatives because such projects can incorporate local resources, practical production activities, and opportunities for technological exposure. Nevertheless, Kizys et al. (2025) also identified implementation challenges, indicating that the presence of community resources alone does not guarantee meaningful educational outcomes.

University-school partnerships may help address some of these challenges by providing technical expertise, learning resources, and professional support. Ferrell and Tharpe (2024) illustrated the potential of university collaboration to strengthen rural science education, suggesting that partnerships can support educational opportunities that may be difficult for schools to develop independently.

The educational emphasis of experiential initiatives may differ across elementary and high school settings. For younger students, participation in practical activities may introduce foundational responsibilities, cooperation, and awareness of environmental or livelihood-related processes. Older students may engage in more complex tasks involving digital applications, resource management, and entrepreneurial activities. A systematic review of student-teacher learning in school-university partnerships also points to the importance of educational context (Zhou & Wong, 2025).

These differences highlight the importance of adapting practical learning initiatives to students' developmental capabilities rather than implementing identical activities across educational levels.

Furthermore, experiential learning should not be evaluated solely according to the number of activities completed or students' participation rates. Meaningful educational development requires attention to what students learn, how they apply acquired knowledge, and whether opportunities exist for reflection and continued practice.

Therefore, school-based initiatives should be understood as potential learning

environments whose educational contributions depend on instructional design, supervision, student participation, and institutional support.

2.4. Community Empowerment through Educational Partnerships

Community empowerment is an important objective of university-community engagement because it emphasizes the development of capabilities that enable individuals and institutions to participate more effectively in activities affecting their lives.

Within rural development, empowerment may involve improved access to knowledge, increased opportunities for participation, stronger institutional capabilities, and greater involvement in local decision-making. However, empowerment should be distinguished from the provision of external assistance or participation in temporary activities.

University-supported educational partnerships can contribute to empowerment by providing opportunities for knowledge acquisition and practical involvement. Lang et al. (2024) emphasized the importance of collaborative knowledge production in rural revitalization, suggesting that development initiatives can become more responsive to local needs when communities participate in shaping activities. Service-learning research in business education further examines the connection between applied learning and responsibility (Mabalay & Castillo, 2026; Rathore & Mahesh, 2025).

The Malaysian study by Diong et al. (2025) further demonstrates how service-learning can connect educational experiences with community participation. Although its primary focus was university students' perspectives, the study illustrates the potential for academic institutions to integrate educational objectives with community-oriented activities.

For school-based initiatives, empowerment may occur at both individual and institutional levels. At the individual level, students may acquire practical knowledge, experience new responsibilities, and develop awareness of technological or entrepreneurial opportunities. At the institutional level, schools may strengthen their capabilities through additional facilities, technical training, and partnerships with external organizations.

Nevertheless, these outcomes represent different dimensions of development and should not be treated as interchangeable. For example, students' participation in aquaculture activities may demonstrate engagement but does not necessarily establish increased decision-making authority. Similarly, the generation of project revenue may provide a financial benefit without demonstrating sustained economic empowerment.

The distinction between participation and empowerment is particularly important in initiatives involving children and adolescents. Practical learning activities may provide valuable educational experiences, but claims regarding broader community empowerment require evidence of changes in capabilities, institutional autonomy, or opportunities for continued participation.

Therefore, the contribution of school-based initiatives to community empowerment should be assessed through observable developments in practical knowledge, student responsibilities, institutional resources, and local capacity to maintain activities. This perspective provides a more cautious and context-sensitive basis for evaluating university-community engagement initiatives.

2.5. Sustainable Rural Development and Institutional Continuity

Sustainable rural development involves strengthening social, educational, economic, and environmental conditions while maintaining the capacity of local institutions and communities to address future needs.

Within university-community engagement, sustainability extends beyond successful project implementation. It also concerns whether participating institutions can retain knowledge, maintain facilities, manage resources, and continue activities after initial external support has been reduced or withdrawn.

Lang et al. (2024) emphasized the importance of collaborative relationships in rural revitalization, demonstrating that development processes involve interactions among universities, local institutions, and community stakeholders. Their findings suggest that sustainable engagement requires attention to institutional relationships and locally responsive development strategies.

The importance of implementation capacity is also evident in research on rural educational partnerships. Kizys et al. (2025) identified challenges associated with integrating place-based learning into school practices and emphasized the need for continued professional development. These findings indicate that introducing practical educational activities is only one component of effective implementation.

For school-based community initiatives, institutional continuity may depend on several conditions, including teacher involvement, administrative commitment, technical capabilities, operational funding, and the availability of maintenance resources.

A university-supported aquaculture project, for example, may establish facilities and provide initial technical training. However, continued operation requires schools to manage feeding schedules, water conditions, equipment maintenance, and other operational responsibilities. Where projects involve income-generating activities, financial planning and resource management become additional considerations.

The sustainability of such initiatives should therefore be assessed across educational, operational, institutional, and financial dimensions.

Educational sustainability concerns whether practical learning opportunities remain available to students. Operational sustainability relates to the ability to maintain equipment and activities. Institutional sustainability concerns the continued commitment and capabilities of participating organizations. Financial sustainability involves the availability of resources necessary to support ongoing operations.

These dimensions are related but should be evaluated separately. For example, the continuation of learning activities does not necessarily indicate financial independence, while the generation of initial revenue does not establish long-term operational sustainability.

Consequently, university-community engagement initiatives should incorporate sustainability planning during project design. Such planning may include teacher training, maintenance arrangements, resource allocation, and mechanisms for monitoring continued implementation. Recent scholarship also connects service-learning with university social responsibility and sustainable development (Çıralı Sarıca, 2026).

2.6. Research Gap and Conceptual Orientation

The reviewed literature demonstrates the potential contributions of university-community engagement to knowledge transfer, experiential learning, and rural educational development.

Lang et al. (2024) provided insights into knowledge co-production and university participation in rural revitalization. Frimpong et al. (2024) examined experiential learning through community engagement, while Diong et al. (2025) explored the implementation and interpretation of service-learning within Malaysian higher education.

Research on rural educational partnerships has also demonstrated the importance of institutional collaboration and locally relevant learning. Ferrell and Tharpe (2024) examined university-school collaboration in rural science education, whereas Kizys et al. (2025) investigated place-based and project-based learning involving community resources and career development.

Although these studies contribute to understanding university engagement and educational partnerships, they address different institutional contexts, participant groups, and developmental objectives. Further comparative investigation is therefore warranted to examine how university-supported school initiatives combine knowledge transfer, practical learning, stakeholder participation, and institutional capacity building across different educational levels. In particular, comparing elementary and high school initiatives may provide insights into how educational context influences the design, implementation, and documented outcomes of university-community engagement activities.

The present study addresses this area of inquiry by examining two school-based aquaculture initiatives in rural Malaysia: High School Pulau Nyior and Sungai Taka Elementary School. The study adopts an integrated conceptual orientation comprising four dimensions: university-community collaboration, knowledge transfer and capacity building, experiential learning and school-level capacity building, and institutional continuity and sustainable rural development.

These dimensions guide the comparative analysis and inform the proposed University-Community Engagement Framework for Sustainable Rural Development. Rather than assuming that university-supported initiatives automatically

produce sustainable development, the framework emphasizes the importance of examining documented project outcomes, institutional capabilities, and the conditions that may support continued implementation. By connecting university engagement with school-level educational development, the study seeks to contribute a context-sensitive perspective on how collaborative initiatives may create opportunities for sustainable rural community development.

3. Methodology

3.1. Research Design

This study adopts a qualitative descriptive multiple-case study approach to examine the role of university-community engagement in advancing sustainable rural development through school-based initiatives. A multiple-case study design provides an appropriate framework for examining community engagement activities implemented in different educational settings while identifying similarities and differences in their implementation processes and documented outcomes.

The study focuses on two university-supported aquaculture initiatives conducted in rural Malaysian schools: High School Pulau Nyior in Kedah and Sungai Taka Elementary School. These initiatives were selected because both involved university-community collaboration and practical learning activities, but differed in their educational contexts, student age groups, technological applications, and implementation approaches.

The comparative approach enables the study to explore how university engagement initiatives can be adapted to different educational environments. Rather than evaluating aquaculture production efficiency, the analysis emphasizes knowledge transfer, student participation, institutional capacity building, and the potential contributions of school-based initiatives to sustainable rural development.

The unit of analysis is the school-based university-community engagement initiative. Each project is examined as an individual case before similarities and differences are considered through cross-case analysis.

3.2. Research Setting and Case Selection

The study examines two school-based aquaculture initiatives implemented through community engagement activities involving Universiti Sains Malaysia and participating schools.

The first case involves High School Pulau Nyior, located in Kedah, Malaysia. The project was implemented in 2024 to introduce aquaculture activities supported by digital technology. The initiative involved the establishment of an aquaculture facility comprising 12 fish tanks, a water treatment system, and digital monitoring components using Blynk technology. The project also included the provision of equipment and technical assistance through collaboration with external stakeholders.

Students participated in aquaculture-related activities, including fish feeding, water management, and monitoring of production processes. The project pro-

vided opportunities for students to acquire practical knowledge while gaining exposure to technology-assisted aquaculture and basic entrepreneurial activities. Fish sales generated revenue that was subsequently used to support school-related educational needs.

The second case involves Sungai Taka Elementary School, where a school-based aquaculture initiative was implemented in 2024. The project involved six aquaculture tanks, including four tanks for catfish and two for climbing perch. Students from Grades 4, 5, and 6 participated in practical activities under teacher supervision.

The elementary school initiative emphasized early exposure to aquaculture, responsibility, teamwork, and basic practical skills. Students were assigned tasks related to fish feeding, water monitoring, and tank maintenance. The project also provided opportunities for teachers to incorporate practical learning activities into the school environment.

Following the implementation of the aquaculture initiative, the school introduced a hydroponic activity. This subsequent development is considered an example of school-level initiative expansion, although its long-term sustainability has not been established.

The two cases were selected purposively because they provide contrasting examples of university-supported school-based initiatives at the high school and elementary school levels. Their inclusion enables comparison of implementation approaches, educational activities, stakeholder participation, and documented institutional outcomes.

3.3. Sources of Data

The study draws on existing project information and documentation associated with the implementation of the two school-based aquaculture initiatives.

For High School Pulau Nyior, available project information includes implementation records, descriptions of aquaculture infrastructure, technological applications, student participation activities, and documented fish sales. The project also involved a student questionnaire administered to 30 participants, providing additional information about students' experiences and reported learning outcomes.

For Sungai Taka Elementary School, available information includes project implementation descriptions, student activity arrangements, teacher-supervised practical activities, and records of subsequent school initiatives (**Table 1**).

The project documentation was examined to identify evidence relating to implementation activities, institutional collaboration, student participation, infrastructure development, and reported project outcomes. The evidence inventory distinguishes between records associated with High School Pulau Nyior and Sungai Taka Elementary School, allowing the findings to be traced to their respective project sources. The analysis focuses on documented activities and outcomes, while recognizing that the availability and completeness of supporting records

may differ between the two initiatives.

Table 1. Summary of available project information and reported outcomes.

Evidence category	High School Pulau Nyior	Sungai Taka Elementary School
Project implementation	2024 project records	2024 project records
Infrastructure	12 tanks, water treatment system, Blynk technology	6 tanks: 4 catfish and 2 climbing perch
Student activities	Feeding monitoring, maintenance	Teacher-supervised feeding and maintenance
Financial outcomes	Fish sales of RM1900 and RM3200	No financial outcome established
Subsequent developments	Initial production and sales	School-led hydroponic activity

The study distinguishes between documented project outputs, reported educational experiences, and broader developmental outcomes. Project outputs include the establishment of aquaculture facilities and implementation of learning activities. Educational experiences relate to students' participation in practical tasks and exposure to aquaculture knowledge. Broader outcomes, such as community empowerment and sustainable rural development, are interpreted cautiously because they require evidence extending beyond immediate project implementation.

The analysis does not assume that participation in school-based activities necessarily produces long-term economic empowerment or sustainable development.

As the original initiatives involved schoolchildren, the secondary analysis required particular attention to the appropriate use of student-related information. The reporting of findings was restricted to project-level information and aggregated student responses, where applicable. Individual students were not identified in the manuscript. The reuse of original project records and questionnaire information was subject to the applicable institutional permissions and ethical requirements.

3.4. Data Analysis

The study used a descriptive cross-case approach to compare the documented implementation processes and outcomes of the two initiatives.

The comparison was organized around four analytical dimensions derived from the literature review and aligned with the proposed conceptual framework:

University-community collaboration and stakeholder participation.

Knowledge transfer and practical skills development.

Student participation and institutional capacity building.

Project continuity and potential contributions to sustainable rural development.

Within-case analysis focused on the implementation processes and documented outcomes of each initiative. For High School Pulau Nyior, particular attention was given to technology-supported aquaculture activities, student partic-

ipation, and the use of project-generated revenue for educational purposes.

For Sungai Taka Elementary School, the analysis focused on early practical learning experiences, teacher supervision, student responsibilities, and the school's subsequent introduction of hydroponic activities.

Cross-case comparison was used to identify similarities and differences between the two initiatives, particularly in relation to educational level, technological integration, stakeholder involvement, learning activities, and opportunities for institutional continuity.

Project information was organized separately for each school according to the four analytical dimensions. Evidence relating to infrastructure, technological applications, student activities, institutional involvement, financial outcomes, and subsequent initiatives was identified and categorized. The two cases were then compared to examine similarities and differences in project implementation and documented outcomes.

Particular attention was given to distinguishing observable project outputs from reported educational experiences and broader developmental outcomes. Where the available documentation did not establish measurable changes in student competencies, institutional independence, or long-term sustainability, conclusions were limited to the activities and outcomes supported by the available evidence.

The analysis was conducted by the author using the available information from both school initiatives. As the projects were originally implemented as community engagement activities rather than formal research studies, detailed records were not consistently maintained. Consequently, the comparison was restricted to information that could be established from the available project materials. Where supporting information was incomplete or unavailable, no additional assumptions were made regarding project outcomes.

The analysis was descriptive and interpretive rather than causal. Accordingly, the study does not seek to establish that university-community engagement directly caused improvements in students' academic performance, household income, or long-term community development.

3.5. Analytical Framework

The study used an analytical framework informed by the literature on university-community engagement, knowledge transfer, experiential learning, and sustainable rural development.

The framework comprises four interconnected dimensions.

The first dimension, university-community collaboration, refers to the relationships established among universities, schools, technical agencies, funding organizations, and other participating stakeholders. These relationships provide the institutional foundation for implementing community-based educational initiatives.

The second dimension, knowledge transfer and capacity building, concerns the

exchange of technical knowledge, practical skills, and organizational capabilities through training and project participation.

The third dimension, experiential learning and school-level capacity building, focuses on opportunities for students to participate in supervised practical activities and on the development of institutional resources that support applied learning. Student participation is interpreted as educational engagement rather than demonstrated empowerment, while school-level capacity building is examined through documented facilities, learning activities, and institutional involvement.

The fourth dimension, institutional continuity and sustainable rural development, considers the extent to which schools demonstrate the capacity and commitment to maintain or expand project activities beyond their initial implementation.

These dimensions guide the comparison of the two cases and provide the basis for developing a proposed university-community engagement framework.

3.6. Trustworthiness and Study Limitations

The credibility of the study depends on the consistency and accuracy of the available project documentation and the extent to which reported outcomes can be supported by identifiable evidence.

Because the two initiatives were implemented in different educational settings and involved different groups of students, their outcomes are not assumed to be directly equivalent. Differences in student age, project design, technological resources, and institutional responsibilities are considered when interpreting the cases.

The study also recognizes limitations associated with relying on existing project information. The availability and detail of documentation may differ between the two schools, and some reported outcomes may reflect observations made during project implementation rather than independently measured developmental changes.

Furthermore, the study does not include longitudinal evidence demonstrating sustained improvements in household income, community economic conditions, or students' future employment opportunities.

Consequently, the findings are interpreted as context-specific insights into university-community engagement rather than generalizable evidence of long-term rural development outcomes.

The proposed conceptual framework should therefore be regarded as an analytical contribution that may inform future research and community engagement practices, rather than an empirically validated model.

4. Findings

4.1. University-Community Collaboration and Stakeholder Engagement

The two school-based aquaculture initiatives illustrate how university-community engagement can facilitate collaboration among higher education institutions,

schools, technical agencies, and external stakeholders. Although both projects were implemented in different educational settings, their implementation reflected a common approach in which university involvement provided opportunities to introduce practical learning activities beyond conventional classroom instruction.

At High School Pulau Nyior, the aquaculture initiative was implemented in 2024 through collaboration involving Universiti Sains Malaysia, the participating school, funding organizations, and technical partners. The project received financial support from Maybank Islamic Asset Management and involved technical contributions from relevant agencies, including institutions providing assistance with aquaculture infrastructure and technological applications.

The initiative involved the establishment of an aquaculture facility comprising 12 fish tanks, a fish-rearing structure, and water management infrastructure. Digital monitoring components were incorporated through the use of Blynk technology. These resources enabled the school to introduce aquaculture activities that combined practical production processes with exposure to digital applications.

The implementation process required coordination among the university, school administrators, teachers, and external partners. University involvement facilitated the organization of the initiative, while technical partners contributed specialized knowledge and infrastructure support. Teachers played an important role in supervising student participation and coordinating day-to-day activities within the school.

At Sungai Taka Elementary School, the aquaculture initiative was implemented in 2024 using a smaller-scale approach adapted to elementary education. The project involved six fish tanks and practical activities designed for students in Grades 4 through 6. Teachers supervised student participation and supported the organization of routine aquaculture tasks.

The comparison indicates that university-community collaboration can accommodate different educational contexts. While the high school initiative incorporated digital technology and production-related activities, the elementary school project emphasized basic practical learning and supervised student responsibilities.

Across both cases, school participation was essential to project implementation. The initiatives therefore illustrate the importance of combining university resources and external support with the operational involvement of participating schools.

4.2. Knowledge Transfer and Practical Skills Development

Knowledge transfer represented a central component of both school-based initiatives. Through practical aquaculture activities, students were introduced to knowledge and skills associated with fish cultivation, water management, feeding procedures, and routine maintenance.

At High School Pulau Nyior, students were exposed to aquaculture activities

supported by digital technology. The incorporation of Blynk technology provided opportunities to become familiar with digital monitoring applications in a practical production environment. Students participated in activities involving fish feeding, observation of water conditions, and routine aquaculture management.

The project also provided opportunities to connect technical knowledge with basic production and resource management processes. Rather than relying exclusively on classroom instruction, students were able to observe and participate in activities requiring the application of practical knowledge.

The questionnaire was administered to 30 participating students solely to obtain feedback on their experiences with the aquaculture project. As the initiative was originally designed as a community engagement activity rather than a formal research study, the questionnaire was not intended to measure changes in students' competencies or learning outcomes. Accordingly, the questionnaire is mentioned only as part of the project implementation and is not used as evidence of measurable educational improvement.

At Sungai Taka Elementary School, knowledge transfer occurred through age-appropriate practical activities. Students from Grades 4 through 6 participated in fish feeding, water observation, and tank maintenance under teacher supervision.

The elementary school project emphasized repeated exposure to practical tasks, allowing students to become familiar with basic aquaculture responsibilities. Teachers observed students' participation during project activities, providing opportunities to monitor their engagement and understanding of assigned tasks.

The comparison suggests that practical knowledge transfer can be adapted to students' educational levels. The high school initiative offered exposure to more technologically integrated activities, while the elementary school initiative emphasized foundational practical skills and routine responsibilities.

These findings illustrate how university-supported school initiatives can provide opportunities for applied learning through activities that connect technical knowledge with practical experience.

4.3. Student Participation and School-Level Capacity Building

Student participation was a defining feature of both aquaculture initiatives. Rather than limiting students to observing project activities, the initiatives provided opportunities for them to participate directly in routine aquaculture management.

At High School Pulau Nyior, students participated in fish-rearing activities and gained exposure to production processes involving feeding, monitoring, and maintenance. The project also introduced students to the economic dimensions of aquaculture through fish production and sales.

Project records indicate that fish sales generated approximately RM1900 during an initial sales period and RM3200 during a subsequent sales period. Revenue generated through these activities was used to support school-related educational needs, including expenses associated with students' examinations.

These outcomes demonstrate that the project generated financial resources that could be directed toward educational purposes. However, the available information does not establish whether the initiative produced sustained financial benefits or measurable improvements in household economic conditions.

At Sungai Taka Elementary School, student participation focused primarily on the development of basic responsibilities and cooperative learning. Students were assigned practical tasks involving feeding and maintenance, with teachers providing supervision and guidance.

Teacher observations indicated that students demonstrated interest and engagement during the activities. The opportunity to participate in managing living organisms also introduced students to responsibilities associated with regular care and maintenance.

At the institutional level, both projects provided schools with additional practical learning resources. The high school initiative established infrastructure for technology-supported aquaculture, while the elementary school project introduced facilities that could support continued hands-on learning.

These developments represent forms of school-level capacity building. Nevertheless, they should not be interpreted as conclusive evidence of broader community empowerment without additional information about changes in decision-making capabilities, institutional independence, or longer-term socioeconomic outcomes.

4.4. Cross-Case Analysis of the Two School-Based Initiatives

A comparison of the two initiatives reveals similarities in their underlying engagement approach alongside differences in implementation and educational emphasis.

Both projects involved university-supported aquaculture activities designed to introduce students to practical knowledge and skills. In both settings, teachers played an important role in coordinating student participation and maintaining routine activities.

However, the projects differed in scale, technological integration, student responsibilities, and the types of outcomes documented.

High School Pulau Nyior implemented a larger aquaculture facility supported by digital monitoring technology. The initiative introduced students to technical applications and production-related activities while generating revenue that was used for educational purposes.

In contrast, Sungai Taka Elementary School implemented a smaller aquaculture initiative emphasizing early practical learning, supervised responsibilities, and student participation. Its documented outcomes were primarily associated with educational engagement and the development of school-based activities (**Table 2**).

The cross-case analysis indicates that university-community engagement can support different forms of educational and institutional development depending on the characteristics of participating schools.

Table 2. Cross-case comparison of university-supported school-based aquaculture initiatives.

Dimension	High School Pulau Nyior	Sungai Taka Elementary School
Implementation	2024	2024
Education level	High school	Elementary school
Aquaculture facilities	12 fish tanks	6 fish tanks
Technology integration	Blynk digital monitoring technology	Primarily manual activities
Student participation	Feeding, monitoring, maintenance, and production-related activities	Feeding, water observation, and tank maintenance
Learning emphasis	Technical knowledge, digital exposure, and entrepreneurial awareness	Basic practical skills, responsibility, and cooperation
Financial outcomes	Fish sales generated revenue for school educational needs	No financial outcomes established
Institutional development	Establishment of technology-supported aquaculture infrastructure	Establishment of practical aquaculture learning facilities
Subsequent initiatives	Continued aquaculture-related activities subject to verification	Introduction of a school-led hydroponic activity
Sustainability evidence	Initial production and sales documented; long-term continuity not established	Subsequent activity documented; long-term continuity not established

Note: The comparison is based on available project information. Differences in implementation scale and educational context limit direct comparisons of outcomes.

The high school initiative demonstrates how practical learning activities can incorporate digital technology and expose students to production-related economic processes. The elementary school initiative illustrates how similar engagement principles can be adapted to introduce younger students to basic practical responsibilities.

Although the documented outcomes differ, both cases highlight the importance of aligning project activities with students' developmental stages, available resources, and school-level implementation capabilities.

4.5. Project Continuity and Sustainability

The sustainability of university-supported school initiatives depends on whether participating institutions can maintain activities, apply acquired knowledge, and develop the capacity to manage resources beyond initial project implementation.

At High School Pulau Nyior, the establishment of aquaculture infrastructure and the completion of fish production and sales activities provide evidence of initial operational implementation. The generation of revenue for educational purposes also illustrates the project's potential to support school-level resource mobilization.

However, the available project information does not establish whether fish pro-

duction and revenue generation continued over an extended period or whether the school developed sufficient financial and technical independence to maintain the initiative without external assistance.

At Sungai Taka Elementary School, the subsequent introduction of a hydroponic activity represents an additional school-led initiative following the implementation of the aquaculture project. This development suggests that the school explored opportunities to extend practical learning beyond the original aquaculture activities.

Nevertheless, the introduction of a subsequent activity does not, by itself, demonstrate long-term sustainability. Additional evidence would be required to determine whether the hydroponic initiative was maintained, integrated into school activities, or supported through stable institutional resources.

Across both cases, teacher involvement emerged as an important operational feature because routine project activities depended on school-level supervision and coordination. The ability of schools to maintain practical learning activities may therefore be influenced by teacher commitment, technical capabilities, resource availability, and administrative support.

Taken together, the two cases provide evidence of initial institutional capacity development and opportunities for continued practical learning. However, conclusions regarding long-term sustainable rural development remain provisional because longitudinal evidence of community-level economic, educational, and institutional outcomes is not yet available.

5. Discussion

5.1. University-Community Engagement as a Catalyst for Rural Development

The findings of this study highlight the potential of university-community engagement to strengthen educational opportunities and institutional capabilities in rural communities. The two school-based aquaculture initiatives demonstrate how universities can contribute to local development by connecting academic expertise, technical resources, and external partnerships with practical educational activities. Rural partnership studies similarly emphasize institutional engagement and local perspectives (Harvey et al., 2024; Lammert et al., 2025; Paulson & Davis, 2024).

At High School Pulau Nyior, university involvement facilitated the establishment of an aquaculture learning environment incorporating digital technology, operational equipment, and opportunities for student participation. At Sungai Taka Elementary School, the initiative introduced practical aquaculture activities appropriate for younger students, emphasizing supervised participation and foundational skills development. Although the projects differed in scale and technological complexity, both illustrate how university-supported initiatives can extend educational opportunities beyond conventional classroom activities.

These observations are consistent with Lang et al. (2024), who emphasized the

importance of collaborative knowledge production in university-supported rural revitalization. Their study suggests that university engagement can become more responsive to local development needs when academic expertise is integrated with community participation.

Similarly, Guo and Lin (2025) examined an ecological university-school partnership in China and demonstrated how collaborative knowledge production can connect academic research with educational practice. Their findings reinforce the importance of partnerships that recognize schools as active participants rather than passive recipients of external assistance.

The present study extends this discussion to school-based aquaculture initiatives in rural Malaysia. In this context, university-community engagement involved not only educational collaboration but also the establishment of practical learning facilities and the introduction of activities associated with local livelihood opportunities.

However, the implementation of these initiatives should not be interpreted as direct evidence of broader rural economic development. Rather, the documented activities demonstrate contributions to educational resources, practical learning opportunities, and school-level capacity development that may support longer-term community development.

5.2. Knowledge Transfer and Experiential Learning as Mechanisms of Capacity Building

Knowledge transfer and experiential learning emerged as important dimensions of the two school-based initiatives. Both projects created opportunities for students to participate in practical activities, although the nature and complexity of these experiences differed according to educational level.

At High School Pulau Nyior, students were introduced to aquaculture production activities supported by digital monitoring technology. The integration of technological applications provided opportunities to connect practical production processes with digital learning experiences. Students were also exposed to aspects of aquaculture management and the potential commercial value of fish production.

At Sungai Taka Elementary School, students participated in supervised activities involving fish feeding, observation, and routine maintenance. These activities emphasized basic responsibilities and practical involvement rather than advanced technological or entrepreneurial competencies.

The findings correspond with Frimpong et al. (2024), who highlighted the educational value of experiential learning through community engagement. Their research suggests that practical participation can connect learning with real-world experiences and encourage students to apply knowledge in meaningful contexts.

Similarly, Kizys et al. (2025) demonstrated the potential of place-based and project-based learning to connect rural educational activities with community resources and career-related experiences.

The Malaysian study by Misiran et al. (2025) provides an additional perspective on the integration of technology, knowledge transfer, and community engagement. Their research introduced a technology-assisted framework for a community STEM sustainability program, emphasizing structured implementation and the use of digital tools to support engagement activities.

The present study contributes to this discussion by illustrating how aquaculture initiatives can provide practical learning opportunities across different school levels. The high school project incorporated digital technology and production-related activities, whereas the elementary school project focused on introductory skills and supervised participation.

Nevertheless, participation in these activities does not independently establish measurable improvements in digital literacy, entrepreneurial competencies, or cognitive development. Such outcomes would require appropriate assessments conducted before and after participation or other systematic evidence of learning.

Accordingly, the findings are best interpreted as evidence of opportunities for experiential learning and knowledge exposure rather than definitive proof of educational effectiveness.

5.3. School-Level Capacity Building and Student Participation

School-level capacity building emerged as an important contribution of the university-community engagement initiatives examined in this study. Both projects provided participating schools with additional educational resources and opportunities to integrate practical learning activities into their existing school environments.

At High School Pulau Nyior, the establishment of aquaculture facilities and the integration of digital monitoring technology expanded the school's capacity to provide technology-supported experiential learning. Students participated in aquaculture activities involving feeding, monitoring, and maintenance. The documented sale of harvested fish also generated revenue that was directed toward school-related educational needs. These outcomes demonstrate initial resource development and operational participation rather than sustained economic empowerment.

At Sungai Taka Elementary School, the initiative provided younger students with opportunities to undertake supervised responsibilities involving fish feeding, water observation, and routine maintenance. Teacher observations indicated student interest and engagement during project activities. The school's subsequent introduction of hydroponic activities also illustrated an opportunity to expand practical learning activities beyond the original aquaculture initiative.

These findings suggest that university-supported school initiatives can strengthen institutional resources and create opportunities for student participation across different educational settings. However, supervised participation should not be equated with empowerment, as the available evidence does not demonstrate increased stu-

dent decision-making authority or institutional independence.

Consequently, the contributions of these initiatives are best understood in terms of school-level capacity building, educational resource development, and opportunities for experiential learning. Further research involving longitudinal observations and systematic assessments of institutional capabilities would be required to establish whether these developments contribute to broader community empowerment and sustainable rural development.

5.4. Sustainability and Institutional Ownership

Sustainability is a central consideration in evaluating university-community engagement because the long-term value of development initiatives depends partly on whether participating institutions can maintain activities beyond their initial implementation.

The two aquaculture projects illustrate different aspects of institutional continuity. At High School Pulau Nyior, the establishment of aquaculture facilities and the generation of revenue from fish sales demonstrated the operational potential of the initiative. At Sungai Taka Elementary School, the introduction of hydroponic activities following the aquaculture project suggests opportunities for extending practical learning within the school environment.

Nevertheless, these observations do not establish long-term sustainability. Continued operation requires ongoing access to technical knowledge, operational resources, maintenance support, and institutional commitment.

Kizys et al. (2025) highlighted challenges associated with implementing place-based learning in rural schools, including the need for professional development and appropriate instructional practices. Their findings suggest that effective implementation requires continued support rather than the initial provision of resources alone.

Similarly, Hadar and Baharav (2025) emphasized the importance of collaborative learning cultures within university-school partnerships. Their study indicates that educational partnerships may contribute to institutional development when teachers participate actively in knowledge creation and professional learning.

These perspectives suggest that the sustainability of school-based aquaculture initiatives should be considered across several dimensions.

Educational sustainability concerns whether students continue to have access to practical learning activities. Operational sustainability relates to the maintenance of facilities and production processes. Institutional sustainability involves the commitment and capabilities of teachers and school administrators. Financial sustainability concerns the availability of resources required for continued operation.

The findings of the present study provide preliminary indications of institutional engagement and opportunities for project continuity. However, additional longitudinal evidence would be necessary to determine whether the initiatives remain operational, financially viable, and educationally beneficial over time.

5.5. Proposed University-Community Engagement Framework for Sustainable Rural Development

Drawing on the comparative analysis and relevant literature, this study proposes a University-Community Engagement Framework for Sustainable Rural Development.

The framework integrates four interconnected dimensions: university-community collaboration, knowledge transfer and capacity building, experiential learning and school-level capacity building, and institutional continuity and sustainable rural development.

The first dimension, university-community collaboration, emphasizes the establishment of partnerships among universities, schools, technical organizations, and other relevant stakeholders. Such collaboration provides an institutional foundation for identifying educational needs, mobilizing resources, and coordinating project implementation.

The second dimension, knowledge transfer and capacity building, concerns the introduction and adaptation of technical knowledge, practical skills, and institutional capabilities. This dimension recognizes that the provision of facilities and equipment must be accompanied by opportunities for learning and practical application.

The third dimension, experiential learning and school-level capacity building, emphasizes opportunities for supervised student participation and the development of institutional resources that support practical education. This dimension recognizes that participation in learning activities can provide valuable educational exposure without necessarily demonstrating individual empowerment or increased decision-making authority.

The fourth dimension, institutional continuity and sustainable rural development, emphasizes the conditions necessary to maintain activities beyond initial implementation. These conditions include stakeholder commitment, operational resources, technical support, and institutional ownership.

The framework draws conceptually on Lang et al. (2024), who emphasized collaborative knowledge production in rural development, and Guo and Lin (2025), who demonstrated the importance of ecological partnerships involving universities and schools.

It is also informed by Misiran et al. (2025), whose technology-assisted community engagement framework emphasizes structured implementation, evaluation, and continuous improvement.

Unlike approaches that focus exclusively on immediate educational activities, the proposed framework integrates collaboration, learning, institutional development, and continuity within a single conceptual structure.

The framework should be understood as a conceptual contribution derived from the comparative interpretation of two initiatives rather than as a statistically validated model. Further research involving additional schools, longitudinal observations, and systematic evaluation would be required to assess its applicability across different rural contexts (**Figure 1**).

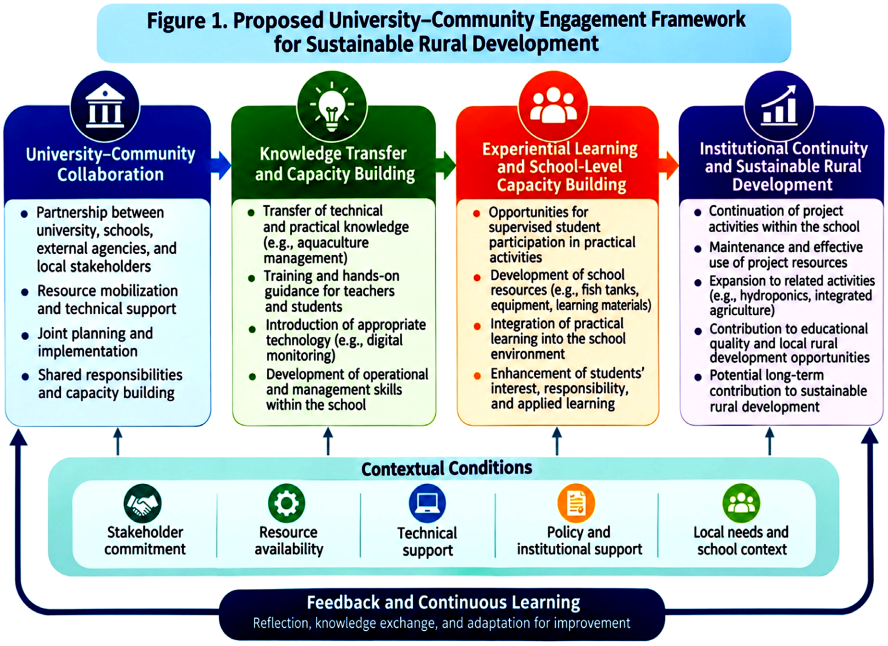

Figure 1. Presents the proposed conceptual relationships.

5.6. Theoretical and Practical Implications

The findings offer several implications for research and practice. From a theoretical perspective, the study contributes to the literature on university-community engagement by integrating knowledge transfer, experiential learning, school-level capacity building, and institutional sustainability within the context of school-based rural development initiatives.

Previous studies have examined university engagement in rural revitalization (Lang et al., 2024), community-based experiential learning (Frimpong et al., 2024), and university-school partnerships (Ferrell & Tharpe, 2024; Guo & Lin, 2025).

The present study brings these perspectives together by examining how university-supported aquaculture activities can be adapted to different educational settings while contributing to school-level learning opportunities and institutional resources.

From a practical perspective, the findings suggest that universities should design community engagement initiatives according to the educational characteristics and institutional capabilities of participating schools.

For elementary schools, initiatives may prioritize supervised activities, basic responsibilities, and introductory practical skills. For high schools, projects may incorporate more advanced technological applications, production management, and entrepreneurial learning opportunities.

The findings also highlight the importance of involving teachers and school administrators throughout project implementation. Institutional participation is essential because schools are responsible for managing activities after the initial university-supported phase.

Furthermore, universities and funding organizations should consider sustainability planning from the beginning of project development. This may include technical training, operational procedures, maintenance arrangements, and mechanisms for monitoring educational and institutional outcomes.

Finally, the study suggests that university-community engagement should be evaluated using indicators that extend beyond project completion. Relevant indicators may include the continuation of activities, maintenance of facilities, teacher participation, documented student learning, and the ability of schools to manage resources independently.

Such evaluations would provide stronger evidence of whether school-based initiatives contribute to sustainable rural development over time.

6. Conclusion

This study examined the contributions of university-community engagement to rural educational development through two school-based aquaculture initiatives implemented at High School Pulau Nyior and Sungai Taka Elementary School in Malaysia. Using a qualitative descriptive multiple-case study approach, the study explored how university-supported initiatives created opportunities for knowledge transfer, experiential learning, student participation, and institutional capacity building within different educational contexts.

The findings highlight the value of integrating academic expertise with locally relevant educational activities. At High School Pulau Nyior, the incorporation of digital technology into aquaculture activities provided opportunities for students to engage with technological applications, fish production processes, and basic entrepreneurial practices. Revenue generated from fish sales also contributed to the school's educational needs, demonstrating how practical learning initiatives can provide additional institutional benefits. In contrast, the initiative at Sungai Taka Elementary School emphasized supervised participation, practical responsibilities, and early exposure to livelihood-related skills. The school's subsequent introduction of hydroponic activities further suggested opportunities for extending experiential learning beyond the original project.

The comparison illustrates that university-community engagement initiatives can be adapted to different educational levels, institutional capabilities, and local priorities. Rather than applying a standardized intervention, universities can work collaboratively with schools to design activities that respond to students' developmental needs and available resources. This context-sensitive approach is particularly important in rural communities where educational opportunities and institutional capacities may vary.

The principal contribution of this study is the proposed University-Community Engagement Framework for Sustainable Rural Development. The framework integrates four interconnected dimensions: university-community collaboration, knowledge transfer and capacity building, experiential learning and school-level capacity building, and institutional continuity and sustainable rural development.

It provides a conceptual perspective on how university-supported educational initiatives may strengthen institutional resources, facilitate practical learning, and create opportunities for continued school-level participation. However, the framework remains conceptual, and its implications for broader community empowerment and long-term sustainable rural development require further empirical investigation.

However, the findings should be interpreted within the study's limitations. The analysis focuses on two initiatives and relies on available project documentation and reported implementation outcomes. Consequently, the study does not establish long-term improvements in student competencies, community economic conditions, or project sustainability. Future research should incorporate longitudinal assessments, direct stakeholder perspectives, and systematic evaluations of educational and institutional outcomes to examine the framework's applicability across different rural settings.

Overall, this study highlights the potential of university-community engagement to strengthen rural educational capacities through collaborative partnerships and practical learning opportunities. Its broader contribution lies in demonstrating how locally responsive educational initiatives can provide a foundation for institutional development, while emphasizing that sustained community benefits depend on continued stakeholder commitment, technical support, and local ownership.

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Ethics Approval and Consent

The school-based aquaculture initiatives were originally implemented in 2024 as university-community engagement projects rather than formal research studies. The primary objectives were to provide practical learning opportunities, develop students' aquaculture-related skills, and support school-level income-generating activities. Permission to conduct the activities and obtain student feedback was granted by the respective school management. The questionnaire administered to 30 students at High School Pulau Nyior was intended solely to obtain feedback on their experiences and perceptions of the project, rather than to collect data for a predetermined research study. Consequently, detailed records of formal research ethics procedures were not maintained as part of the original project implementation. The present article provides a retrospective descriptive analysis of the initiatives based on available project information and reported outcomes. No new data were collected specifically for this manuscript. The findings are presented at the project level without identifying individual students.

Data Availability

The study draws on project documentation, implementation records, and reported outcomes associated with the two school-based aquaculture initiatives. These materials are not publicly available. Requests for access may be directed to the corresponding author, subject to institutional permissions and confidentiality requirements concerning school and student information.

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Conflicts of Interest

The author declares no conflicts of interest.

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